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B70 06041

SUBJECT: Proposed Medical Experiments for the J Missions - Case 320

DATE: June 11, 1970

FROM: P. Benjamin

NASW-417

ABSTRACT

[redacted]

The following medical experiments are being proposed for the J Missions:

Metabolic Rate Assessment: Evaluation of the metabolic cost of operational work tasks during lunar EVA and comparison with ground-based simulation data.

Apollo Time and Motion Study: Evaluation of the differences, correlation, and relative consistency between ground-based simulation and lunar surface task dexterity and locomotion performance.

Total Body Gamma Spectrometry: Detection of changes in total body potassium, total muscle mass, and induced radioactivity as a result of exposure to the space environment.

Bone Mineral Measurement: Determination of the extent of bone mineral changes as a result of exposure to weightlessness and detection of possible remineralization as a result of intervening 1/6 g exposure.

Aerosol Particle Analyzer: Measurement of the size and concentration of aerosol particles, in particular lunar dust, as a function of time in the CM.

Microbial Survival in Lunar Environment: Determination of the type and degree of alteration of microorganisms resulting from exposure to radiation on the lunar surface.

The first four experiments should provide information of value both to the scientific community and to the space program, and are already, in one form or another being carried out informally. Their approval as experiments or Detailed Objectives would probably have only a small additional impact upon the missions and can benefit both the program and the scientific return of the experiments. The Aerosol Particle Analyzer, scheduled to fly on Skylab I, is already developed and has significant application to the problems associated with lunar dust contamination of the CM atmosphere. The last experiment proposes to study a significant problem with serious implications to the future of manned space flight. However, serious problems with respect to the safety and thermal control of the experimental package must be solved and may result in significant weight, size, and timeline impacts upon the mission.

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MEMORANDUM FOR FILE

A series of six medical experiments is being proposed for the J missions and is surveyed in this memorandum. Of these experiments, four are currently being carried out either in the form proposed or in a manner similar to the proposal, in the Apollo flights without formal recognition as experiments. One of the remaining two experiments is scheduled to fly on Skylab and is considered to have possible application in Apollo, and the last is entirely new. There are a number of advantages in formalizing as experiments or Detailed Objectives (DO's) some of the procedures which are being carried out informally at the present time. The designation of these activities as experiments or DO's should result in a more rigorous protocol being carried out, thereby enhancing their value. As experiments or DO's they obtain a status on the objectives priority list, thereby establishing more definitive requirements for crew and ground support activities. In recognizing these activities as experiments the scope of science return from the J missions is broadened beyond the realm of geophysics, geochemistry, and geology. The purpose, procedure, and impact of each experiment are discussed below.

METABOLIC RATE ASSESSMENT

Astronaut metabolic rate is a prime parameter used to determine consumables usage, task scheduling, and traverse planning limits for lunar surface EVA. If an accurate determination of the metabolic cost of various tasks and operations on the lunar surface can be made, a realistic basis is provided for the planning of future lunar surface activities. Correlation of 1/6 g experience on the moon and data obtained in 1 g tests and 1/6 g simulators on the earth can provide a better basis for the prediction of the effects of reduced gravity upon the metabolic costs of various activities. Combined with the data obtained in the Time and Motion Study, described below, the Metabolic Rate Assessment Experiment should help to maximize work efficiency and the functional design of equipment.

Assessment of the metabolic cost of astronaut activities during lunar surface EVA has been carried out in real time and postflight for both Apollo 11 and Apollo 12. To date the most successful method, according to MSC, has been a calorimetric technique which determines the metabolic rate by measuring the Liquid Cooling Garment (LCG) inlet temperature and the change in temperature between the inlet and outlet (ΔT). If all external heat sources can be accounted for accurately, the heat production by the astronaut can be assumed to vary linearly with the change in ΔT and the metabolic rate for each activity can be determined. As a final check, the amount of feedwater remaining in the PLSS at the termination of the EVA is determined as a measure of the overall heat load (metabolic and external) of the EVA.

A second and (by MSC standards) less successful technique for determining the metabolic rate involves determining the O_2 consumed by the astronaut. This is done by measuring the O_2 supply pressure as a function of time and correcting for suit leakage. Since metabolic rate is linearly related to the amount of CO_2 produced, if a Respiratory Quotient (RQ), or ratio of CO_2 produced to O_2 consumed, is assumed, the metabolic rate can be determined. Unfortunately, the determination of an RQ without measurements is difficult at best, and the resulting data is subject to large discrepancies. This problem can be reduced by return of the LiOH canisters to earth for analysis. Determination of the concentration of Li_2CO_3 in the canister yields the total CO_2 produced, and thus the RQ. Therefore, this experiment proposes the return of two LiOH canisters from one EVA. This imposes a 1 lb LM landing weight penalty and 14 lb LM liftoff weight penalty, but together with the LCG ΔT measurements, should provide a better estimate of metabolic costs than either method alone could.

The third method currently in use correlates the heart rate with preflight ergometer tests in which the relationship between metabolic rate and heart rate for each astronaut has been accurately measured. This is the least accurate method, since any deviation in the physical or emotional state from the calibration tests can result in changes in heart rate which are not correlated with metabolic rate. Differences between the tasks performed on the lunar surface and ergometer activity also introduce errors.

Emphasis on the first two methods in coordination, with allowances for suit heat and O_2 leakages determined from test data, and with provision for PLSS feedwater measurement and LiOH canister return, may provide a valuable scientific return with obvious application to operational planning. The accuracy to which detailed metabolic rate information can be deduced from the metabolic cost data obtained is yet to be determined. The extent of the ground test program required is not completely clear. The only impact upon the mission plan indicated in the proposed experiment is the activity, stowage, and weight penalty associated with the canister return and feedwater measurement. None of the activities has a direct impact upon the EVA timeline.

APOLLO TIME AND MOTION STUDY

Comparison and evaluation of preflight simulator and training films; video tapes, films, and kinescopes of lunar surface operations; and possible films of postflight simulations should reveal the correlations, differences, and relative consistency between ground-based and lunar surface task dexterity and locomotion performance. A study of this time and motion data should provide a valuable input to mission planning. Combined with the data obtained in the Metabolic Rate Assessment, described above, the Time and Motion Study can help to maximize work efficiency and the functional design of equipment. For instance, observation and determination of walking rates and correlation with the metabolic rate can lead to the more accurate determination of walk back capability constraints. Evaluation of equipment deployment in the lunar environment can result in an optimization of equipment handling scheduling and methodology, and may suggest possible redesign options which would simplify operation.

Time and motion study has long been an accepted technique in the industrial environment for the optimization of workplace design and operational methods. Visual records of operations have been used extensively for detailed analysis in slow motion. An extensive body of literature in this field has kept pace with the application of an expanding technology to the analysis of the human factors engineering and physiological aspects of human work.

The proposed experiment entails a systematic study of the degree of movement, extent of motor coordination, and task time of lunar surface tasks relative to performance of simular activities on earth. With adequate control and replication the study should be able to indicate the differential effects of reduced gravity upon task performance. As proposed, the tasks to be performed will be selected from the normal complement of lunar surface activities, including walking, running, loping, equipment deployment and manipulation, ingress and egress operations, and equipment transfers. Accordingly, there should be minimal impact upon surface activities.

It is proposed that a film record of these activities be made by a sequence camera in the LM, as in Apollo 11 and 12, and by a second sequence camera operated by one of the astronauts on the surface, as was planned for Apollo 13. As in previous missions, this record can be augmented by observations obtained from the tripod-mounted TV camera in the vicinity of the LM. At science stations the LRV-mounted remote control TV camera can follow astronaut activities, although use of this camera for time and motion study will have to be coordinated with operational requirements and geological priorities.

The value of this type of experiment has already been recognized in the extensive use of simulator films for equipment design evaluation and the analysis of the films, video tapes, and kinescopes returned from past missions to determine future mission techniques. The potential returns to be gained from this experiment are fairly great compared to its minimal impact upon currently planned mission activities.

TOTAL BODY GAMMA SPECTROMETRY

One of the factors of great interest to the medical community and having significant impact upon long duration missions is the degradation of body functions and structure after prolonged exposure to the space environment - in particular, to reduced gravity and radiation. These atrophy effects have been observed in bed rest studies and have been examined closely throughout the history of manned space flight. This experiment investigates these phenomena by measuring the amounts of K^{40} in the body and determining the changes of total body potassium and lean body mass before and after flight. In addition the accumulated radiation exposure of the crew during the mission is determined through measurements of total body induced radioactivity. The effects of such exposure and crew response to radiation will have a definite bearing upon radiation shielding requirements for future manned space flights.

In this experiment each crew member is examined 30 days before launch, as soon after recovery as possible, and about a week after recovery by radiation detecting instruments. The equipment is located in a shielded room, the Radiation Counting Laboratory, below the Lunar Receiving Laboratory. The experiment was conducted on the Apollo 11 and 12 crews. All the equipment and procedures required to conduct this experiment are in existence, and there are no impacts upon the mission (all measurements being pre and post flight).

BONE MINERAL MEASUREMENT

In a companion experiment to the Total Body Gamma Spectrometry, the Bone Mineral Measurement experiment investigates the same phenomenon of body structure degradation due to reduced gravity. Of particular interest is the determination of the degree of bone mineral changes which might result from weightlessness and the extent to which the short exposure to 1/6 g on the lunar surface modifies these changes. The focus is thus upon comparison of demineralization in the CMP as opposed to the CDR and LMP.

In this experiment an X-ray absorption technique is used to measure the bone mineral content of the radius, ulna, and os calcis pre and post flight. The basic investigation of this phenomenon has been carried out since the inception of manned space flight, although this particular format envisions somewhat more rigid control, a slightly modified technique, and extensive comparisons to past and present bed rest studies as a parallel. This experiment is of recognized importance to the future of manned space flight and has no impact upon the mission, all measurements, as in the previously discussed experiment, being pre and post flight.

AEROSOL PARTICLE ANALYZER

Some concern has been voiced over possible hazards resulting from the contamination of the CM environment with lunar dust after the LM has returned from the lunar surface. The extent of pollution of the CM atmosphere can be measured with the Aerosol Particle Analyzer, or nephelometer, which determines the size and concentration of airborne particles. This may help to determine whether the dust presents a hazard to respiration and to provide data to allow design of equipment for dust removal.

The nephelometer proposed for this experiment is a 3.75" x 7.5" x 5.5" self-contained, hand-held, battery-operated 5.5 lb device which requires a minimal amount of crew activity for operation and data recording. The instrument measures concentrations between 500 and 500,000 particles per cubic foot and sizes in 5 discrete ranges from 0.5 to 10 microns. Samples are all taken in the CM daily from launch until after LM docking, 2, 4 and 8 hours after return to the CM, and again daily thereafter. No samples are taken in the LM. The weight and stowage impacts upon the CM are small and only a small timeline impact during the coast portions of the flight is incurred. Of greater concern is the impact upon lunar orbit activities, particularly in the very busy period following LM docking. This may require some modification in the experiment protocol.

The Aerosol Particle Analyzer is scheduled to fly in the Skylab Program, and has been proposed for Apollo because of its applicability to the lunar dust contamination problem. It is being proposed for the J1 and J2 missions. Since the basic development work has already been concluded, technical difficulties in preparation of the hardware would not be expected. Accordingly, the resolution of some minor time allocation problems in lunar orbit would seem to be the only significant question concerning this experiment.

MICROBIAL SURVIVAL IN LUNAR ENVIRONMENT

Exposure of microorganisms to radiation may result in alterations in their genetic structure. It is possible that some of these alterations might increase the pathogenicity or communicability of certain microorganisms, causing common, previously harmless bacteria to become dangerous to the crew. In addition, should these altered bacteria be returned to the earth's biosphere, a potentially dangerous situation may result. The objective of this experiment is to measure quantitatively the effects of lunar surface radiation upon such microorganisms and to evaluate the consequences of radiative alteration.

Four Microbial Environmental Exposure Devices (MEEDs), containers for the microorganisms, would be used for each flight. One would remain on earth as a control and three, in a carrying case, would be loaded on the CM at T-3 days. As proposed in this experiment, the carrying case is transferred to the LM prior to descent and two MEEDs are taken onto the lunar surface at the beginning of an EVA. They are aligned with the sun line, the light covers are removed for 5 minutes, and, at an appropriate time, the MEEDs are returned to the LM and replaced in the carrying case. The case is transferred back to the CM after docking, and is shipped to MSC for analysis as fast as possible after recovery.

The carrying case, containing three MEEDs, is projected to be a 4.0" x 8.0" x 5.0" box weighing 10 lbs. This would impose a penalty upon both LM landed payload and payload returned. In addition, a fair amount of astronaut activity is required to perform this experiment as proposed, and thus it does have a measurable effect upon the mission.

There has been serious concern on the part of the medical community with respect to the effects of reduced gravity and radiation upon bacterial development. A careful study of these effects, as proposed by this experiment, can contribute significantly to the space program. There are, however, what would appear to be some fairly serious flaws in the experiment as it is currently proposed.

The bacterial samples will be exposed to a number of different environments during the course of the experiment, including the earth, moon, and zero gravitational fields; high acceleration of launch and landing; and radiation in the CM, LM, and on the lunar surface. Exactly how these effects are to be separated in the analysis is not clear, although demonstration of pathogenicity from the combination would be a significant result in itself.

If the basic thesis is correct and the combined effects of the space environment do produce a pathogenic bacterial strain, the experiment itself represents a potentially serious danger to the crew, as well as a possible source of contamination of either the moon or the earth. Thus, not only would an extensive study of appropriate quarantine and handling procedures have to be undertaken (as proposed in the EIP), but design of the MEEDs would have to ensure the integrity of the package under worst case earth landing loads, under the wide thermal extremes seen in the course of the mission, and for all conceivable possibilities of mishandling by the crew during the mission or during shipment after return to earth. Such an extensive study will not only take some time - quite probably more than is available to permit the experiment to fly on the J missions - but will quite possibly result in the construction of a considerably larger and heavier package than is currently envisioned.

The shelf life of typical microorganisms is approximately 3 weeks. The time between the preparation of the experiment package and its return to MSC exceeds this value slightly and thus may compromise the scientific return. The experiment proposal states a temperature requirement of 68°±9°F for the MEEDs. It seems improbable that the, presumably, passive thermal control envisioned for these boxes will be capable of maintaining this tight a tolerance over the extremes of temperature that will be encountered on the lunar surface, especially with the light window open. A more complex temperature control system would probably result in a significant increase in size and weight of the package as well as an extended development time. Approval of this experiment would seem to be contingent upon detailed examination and resolution of these questions.

CONCLUSION

Four of the proposed experiments--Metabolic Rate Assessment, Apollo Time and Motion Study, Total Body Gamma Spectroscopy, and Bone Mineral Measurement--should provide information of value both to the scientific community and to the space program, and are already, in one form or another, being carried out informally. They would probably impose only a small additional impact upon the missions, and their designation as experiments or DO's can benefit both the program and the scientific return of the experiments. With the possible exception of a ground test program associated with the Metabolic Rate Assessment, no major additional development is required, and the experiments are essentially ready for the J missions.

The Aerosol Particle Analyzer has significant application to the problems associated with lunar dust contamination of the CM atmosphere. A possible minor problem with respect to timeline impact immediately after LM docking in lunar orbit remains to be resolved. Since it is scheduled to fly on Skylab I, the development of this experiment is complete, and it should be ready to fly on the first J mission.

The Microbial Survival in Lunar Environment experiment proposes to study a problem of great concern to the medical community and with possible serious implications to the future of manned space flight. However, serious problems with respect to the safety and thermal control of the experimental package must be solved, and the extent of weight, size, and timeline penalties must be determined and justified.

Peter Benjamin

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